RELIABILITY EVALUATION OF SABAH TRANSMISSION AND SUB-TRANSMISSION NETWORKS

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ABSTRACT

Reliability planning criteria such N-1 and N-2 are measures of system wide reliability provided by an electricity distribution utility. These criteria also indirectly indicate the utility's Operations and Maintenance (O&M) efficiency, system's ability to transfer load to the neighbouring units in case of cable or equipment failures, response time to locate and isolate a fault and restoration time. This study considerably extends the modelling and evaluation techniques presently used in assessing the reliability of transmission networks. The concepts described lead to a realistic analysis of such systems. The most important features that are described concern the incorporation of value-based analysis, this often being of vital importance. In line with the new regulatory framework, Sabah Electricity Sdn Bhd took the opportunity to enhance its planning methods and approaches by adopting value-based approach to achieve optimum total cost of ownership. This paper presents an actual case study of detailed analysis on the connection schemes and substation configuration for a newly proposed 275/132kV substation. The outcome of the study results in a significant cost saving as compared to traditional approach. It was determined that the evaluation study based on the value-based analysis could save about twenty percent (20%) of project capital expenditure cost.

ABSTRAK

Kriteria Perancangan berdaya harap yang dirujuk sebagai N-1 dan N-2 adalah tanda ukur untuk menganalisa kadar berdaya harap bagi keseluruhan system pembekalan elektrik dari utility bekalan elektrik. Kriteria ini juga menjadi asas penting bagi penyelenggaraan dan operasi serta keboleh daya untuk memastikan bekalan elektrik yang berterusan sekiranya berlaku gangguan kepada sebarang elemen system pembekalan elektrik. Kajian ini teknik memodelkan sistem grid dan penilaian dalam mengkaji kedayaharapan rangkaian system penghantaran. Antara komponen penting dalam kajian ini adalah dengan mengambil kira analisa nilai sesuatu pembangunan projek yang mana sangat penting bagi syarikat utiliti. Selari dengan rangka kerja pembekalan elektrik, Sabah Electricity Sdn Bhd mengambil peluang untuk menambahbaik kaedah perancangan dengan menerapkan kajian nilai demi mencapai kos pembangunan yang optimum.Kertas ini membentangkan kes kajian sebenar berkenaan dengan skema penyambungan yang optimum bagi sistem penghantaran 275kV. Hasil kajian ini akan memberikan penjimatan kos yang signifikan berbanding kaedah tradisi. Hasil kajian juga akan menunjukkan penjimatan sebanyak dua puluh peratus (20%) terhadap kos pembangunan projek melalui penilaian berasaskan nilai.

CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF SYMBOLS AND ABBREVIATIONS

AC	Alternating Current
BRE	Business Risk Exposure
BCR	Benefit Cost Ratio
ECG	East Coast Grid
ENS	Energy Not Supplied
EENS	Expected Energy Not Served
EFOM	Energy Flow Optimizing Model
kV	KiloVolt
km	Kilometre
kw/yr	Kilowatt/year
kWh	KiloWatt hour
MW	MegaWatt
MVA	Mega Volt Ampere
PDF	Probability Distribution Function
PF	Power Factor
p.u	Per unit
PSSE	Power System Simulator for Engineer
SAIDI	System Average Interruption Duration Index
SAIFI	System average Interruption Frequency Index
SESB	Sabah Electricity Sendirian Berhad
SLGC	Sabah Labuan Grid Code
SVC	Static Var Compensation
UTHM	Universiti Tun Hussein Onn Malaysia
VOLL	Value of Loss of Load

CHAPTER 1

INTRODUCTION

1.1 Project Background

A set of appropriate criteria are used to evaluate the reliability of the power provided from Sabah Electricity Sdn Bhd (SESB) through a set of specified delivery points to high voltage consumers and distribution companies. These criteria comprise of N-1 and N-2 planning criteria that refers to equipment element of transmission line. This project will address the delivery point interruption performance concept and present the results obtained from the application of the mentioned planning criteria for newly 275kV transmission system backbone expansion in Sabah Grid.

The obtained results would be analyzed and explained. The past delivery point interruption performance is quantitatively assessed and the major influencing factors are determined. In addition, this project would also assess the value-based approach of transmission line expansion. The findings serve as a guide for determining the optimum investment after considers the transmission system expansion needed. It is also recommended that the application of value-based analysis shall be one of the most important input parameters to the decision making process for expansion and reinforcement schemes.

A transmission development plan outlines the transmission expansion/reinforcement required to ensure power generated can be delivered to the load centers without violating any limits set by the codes/rules/licenses. Under traditional approach, in formulating a transmission development plan, various options for transmission expansion/ reinforcement may be assessed and the least cost option will be recommended. The transmission network shall be planned with a minimum satisfaction of the following principles:

a. Safety (Managing fault level within equipment rating)
b. Adequacy (Ensuring sufficient power to meet demand)
c. Security (Robust system: minimum N-1 or N-2)
d. Reliability (All of the above)
e. Economic (Least Cost Option)

The purpose of this study is to propose and test an improved system to enhance the transmission system reliability of Sabah Grid and to achieve N-1 and N-2 planning criteria. The significant contributions expected through this study are the optimum transmission expansion scheme without jeopardize the 275KV transmission network stability.

1.2 Problem Statements

Presently, the solely fragile 275kV transmission network in Sabah due to frequent tripping has hampered the quality of electricity supply to Sabah. Existing transmission network in Sabah is transverse from West Coast Grid to East Coast Grid with distance about 255km. This transmission line backbone is link the West Coast Grid and East Coast grid with N-1 capacity of 639MVA. Normal power transfer through this line ranging from 60MW to 100MW, which limited due to operational constraint. In the event of this transmission line tripped, the West Coast Grid would experience over frequency condition that would trip the generating sets and subsequently cause the total black out at West Coast Grid. Whilst, the East Coast Grid would experiencing under frequency that also cause total black out at East Coast Grid.

Various approaches have been implemented to overcome these issues by replacing the protection relays and install the disturbance recorder for tripping study. However, the tripping still occurred which the transmission network required a permanent medium term and long term approach to improve the supply performance in Sabah grid. The Figure 1 below shows the mapping of 275kV transmission line.

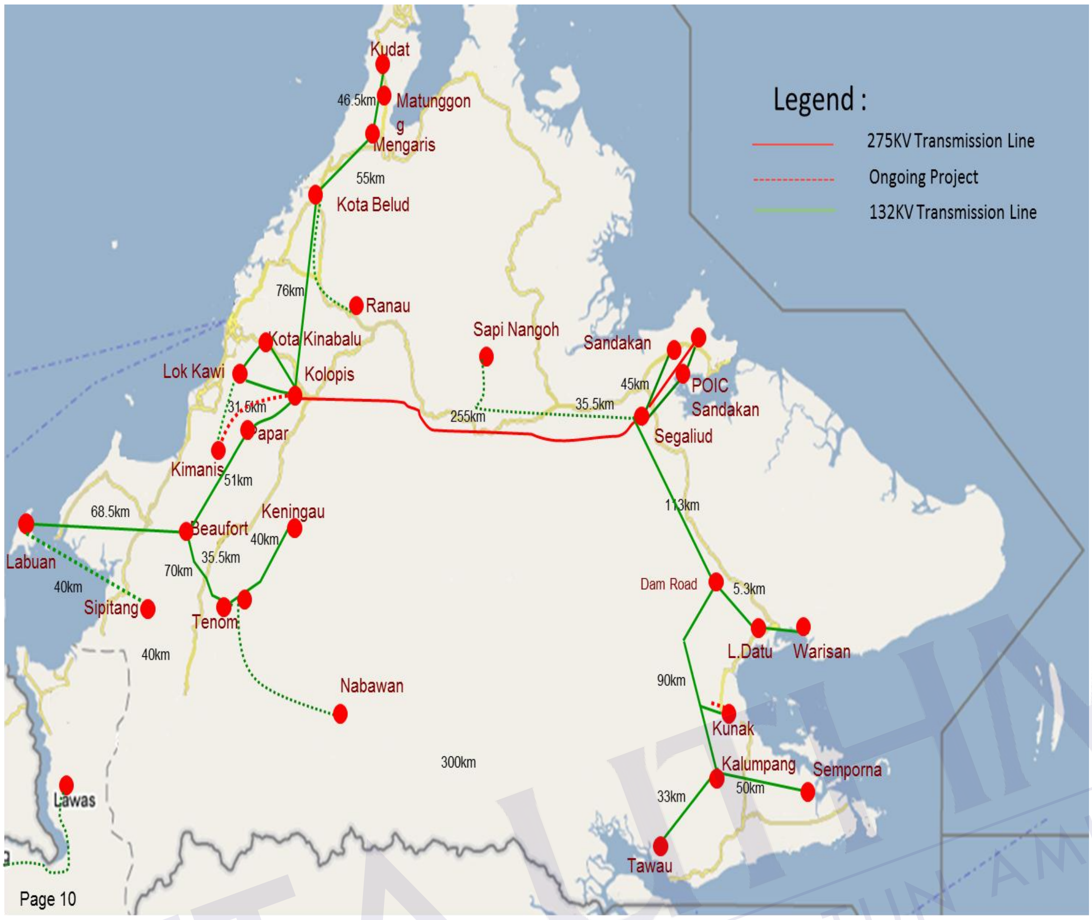

Figure 1.1: Existing Sabah Transmission Network Mapping

Under this study, the existing 275kV transmission network would be studied to determine whether there is a need for another expansion needed namely Southern Link that provide second link of the West Coast Grid and East Coast Grid . All 275kV buses reference of transmission network would be assessed and tripping study to be conducted under load flow analysis to analyse current reliability performance with current generation scenario. Based on load flow analysis, the specific transmission will be assessed under transient study. In the event that the loss of load is higher than permissible value, the development of Southern Link would be needed. The newly development would be further study with Benefit Cost Ratio (BCR) analysis to ensure the development is comply with Labuan and Sabah Grid Code.

The needs to conduct BCR analysis is stated in Sabah and Labuan Grid Code under clause PC5.1.2 as follows,

"Minimally, a (N-1) primary criterion shall be applied to the Transmission Network to determine when reinforcement is required and an N-2 test shall be undertaken to determine the consequences of a second circuit outage during for example maintenance."

"The second transmission circuit outage or interbus transformer outage is intended to assess the amount of load lost under this contingency and its impact on the wider Power System. The Network Planner should consider schemes to provide alternative circuits or interbus transformer capacity, if these can be justified on a cost benefit basis, where an N-2 contingency causes loss of strategic industrial or commercial loads or the loss of more than 95 MW2 of generation."

In summary, the BCR Analysis is required to justify a project identified to mitigate the impact of (N-2) contingency that causes the loss of strategic industrial or commercial loads or the loss of more than 95 MW of generation.

1.3 Project Objectives

The major objective of this research is to study the reliability of Sabah transmission network. Its measurable objectives are as follows:

a. Assess the safety, adequacy, security, reliability and economic of the existing 275KV network under study year 2013 and study year 2023
b. Propose attainable development schemes with respect with the economic analysis

1.4 Project Scopes

This project is primarily concerned with the reliability evaluation of transmission network. The scopes of this project are:

a. Garner all data required of the existing system based on the transmission data.
b. Model the existing system in accordance with Power System Simulator.
c. Conduct the power flow and transient studies on modelled transmission system
d. Based on the previous results, the study areas are tabulated for short and medium term development and system enhancement.
e. Propose attainable scheme of newly second link development

1.5 Thesis structure

In this thesis, it contains five chapters. For the chapter 1 is discussing on the introduction of this project. The introduction tell about the cascading event occur in the Sabah system grid. When cascading event occurs in the system, the system is at risk of total black out.

Chapter 2 is the literature of review. Previous study conducted and journals are selected as a reference for this project. The enhancement proposed in the previous study is taking into account to be implemented if necessary.

Chapter 3 discussed about the methodology. In this chapter, procedures to conduct a study using PSSE software are written. Using this software, few case study are built to be perform in chapter 4.

Chapter 4 are discussing on the result and analysis. Further elaboration is discussed in this chapter. This chapter contain four cases study to determine the weakest point in the system.

Chapter 5 is more to conclusion and future works to enhance and strengthening the Sabah System grid to its reliable operation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Reliability planning criteria such N-1 and N-2 are measures of system wide reliability provided by an electricity distribution utility. These criteria also indirectly indicate the utility's Operations and Maintenance (O&M) efficiency, system's ability to transfer load to the neighboring units in case of cable or equipment failures, response time to locate and isolate a fault and restoration time. This study considerably extends the modeling and evaluation techniques presently used in assessing the reliability of transmission networks. The concepts described lead to a realistic analysis of such systems. The most important features that are described concern the incorporation of value-based analysis, this often being of vital importance. In line with the new regulatory framework, Sabah Electricity Sdn Bhd took the opportunity to enhance its planning methods and approaches by adopting value-based approach to achieve optimum total cost of ownership. This paper presents an actual case study of detailed analysis on the connection schemes and substation configuration for a newly proposed 275/132kV substation. The outcome of the study results in a significant cost saving as compared to traditional approach**.** Enhancing the adequacy and stability of transmission system would improve the supply performance. Findings from reliability evaluation would indicate the type of system improvement needed.

2.2 Theories

Electric power systems vary in size and structural components. However, they all have the same basic characteristics:

a. Are comprised of three phase ac systems operating essentially at constant voltage. Generation and transmission facilities use three-phase equipment.

b. Use synchronous machines for generation of electricity.

c. Transmit power over significant distances of consumers spread over a wide area. This requires a transmission system comprising subsystem operating at different voltage level.

Figure 2.1 illustrates the basic elements of a modern power system. Electric power is produced at generating stations and transmitted to consumer through a complex network of individual components. Under this study, the focus would be mainly on transmission system and sub-transmission system. The transmission system interconnects all major generating stations and main load centres in the system. It forms the backbone of the integrated power system and operates at the highest voltage levels typically 275kV and above. The sub-transmission system transmits the power in smaller scales from transmission substation to distribution substations.

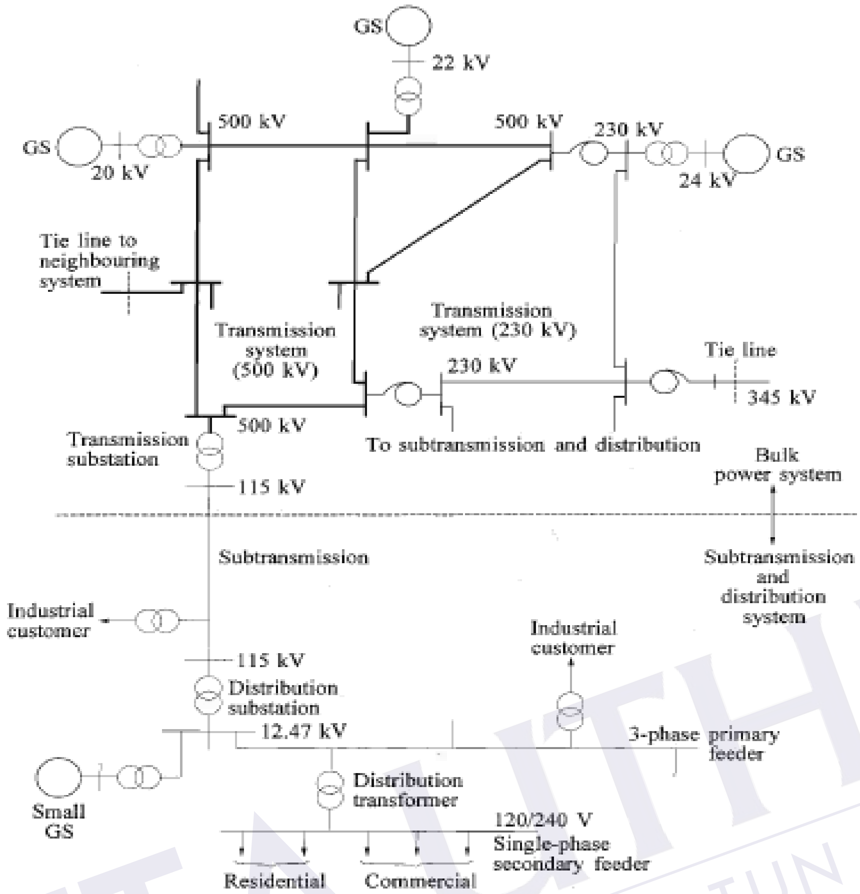

Figure 2.1: Basic elements of power system

In analysing the power system security, the system operating conditions could be classified into five states: normal, alert, emergency, in extremis and restorative. Figure depicts these operating states and the ways in which transition can take place from one state to another. In the normal state, all system variables are within the normal range and no equipment is being overloaded. The system enters the alerts state if the security level falls below a certain limit of adequacy, or if the possibility of a disturbance increases because of adverse weather conditions such as the approach of severe storms. The system has been weakening to the level where a contingency may cause an overloading of equipment that places the system in an emergency state. If the disturbance is very severe, the in-extremis state may result directly from the alert state. Under emergency state, the system may be restored by initiating of emergency control actions such fault clearing and load curtailment.

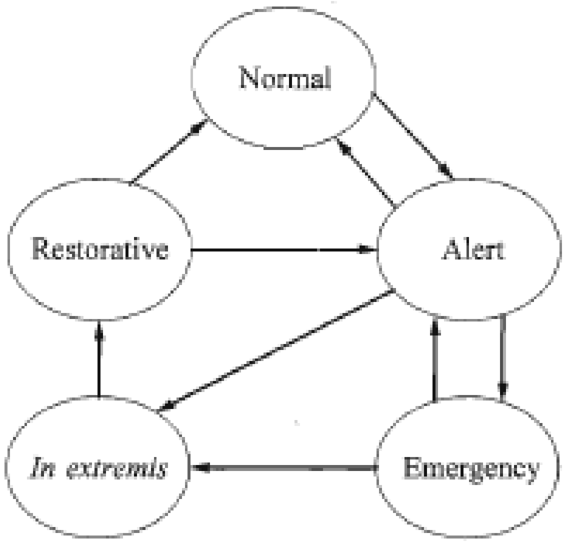

Figure 2.2: Power system operating states

Electric system reliability can be addressed by considering two basic functional aspects of the electric system – Adequacy and Security. Adequacy is the ability of the electric system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements. Security is the ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements. Under this project, the system adequacy would be evaluated through steady state while the system security being evaluated through dynamic analysis. Transient stability is the ability of the power system to maintain synchronism when subjected to a severe transient disturbance such as faults on transmission facilities, loss of generation or loss of large load. Under N-1 contingency occurrence of the double circuit transmission line, the ability of the energy transferred is also reduced. Figure 2.3 illustrated the relation on performance of power transfer under single circuit and double circuit.

$$P_E = E'E_B \sin\delta / X_T = P_{MAX} \sin\delta$$

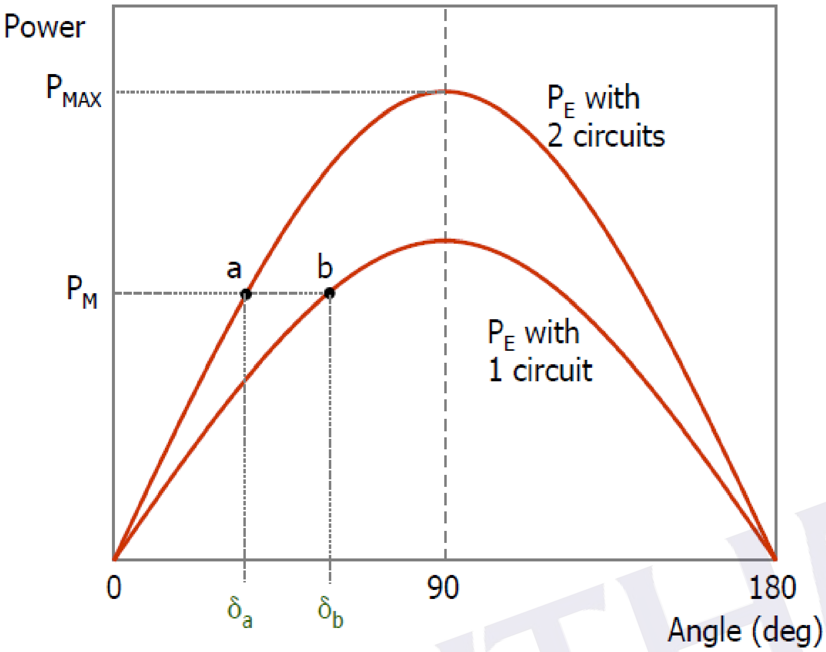

Figure 2.3: Power-Angle Equations

In the event the voltage problems develop into instabilities, these are called voltage instabilities or voltage collapses. Voltage collapse cause a very low voltages to be experienced in the system and normally low voltages arise at high load conditions. Voltage collapse situations may involve both the sending-end and receiving-end systems, and just the receiving-end system. In most cases, the transmission line is heavily loaded. The power factor of the load changes the shape of the P-V curve (refer to Figure 2.4) and the point of voltage collapse. Lagging power factor loads result in voltage collapse for lower level of transfer than do leading power factor loads because of their increased VAR demand.

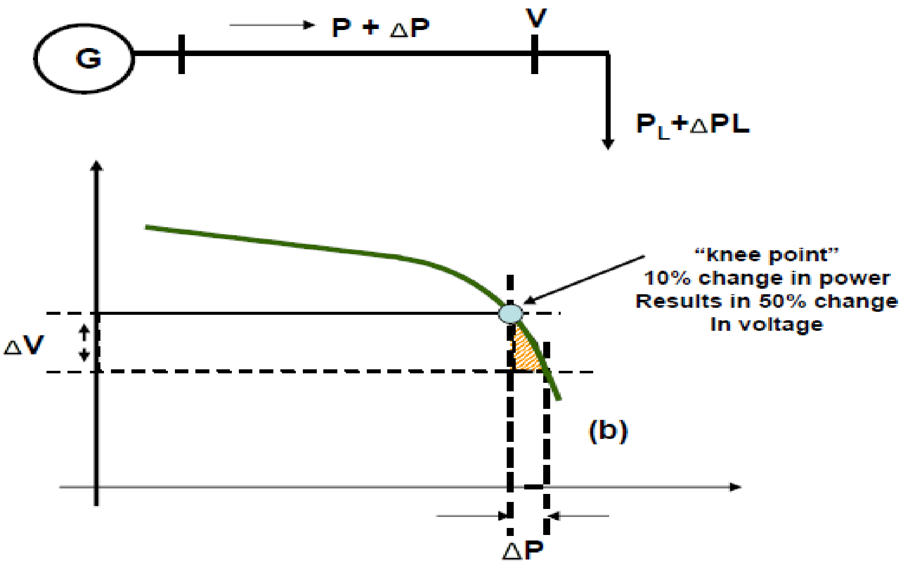

Figure 2.4: P-V Curve

The load power factor (PF) of the system would tremendously affect the transmission line power transfer. The lower the PF, the stability of the line would also being reduced. The relation on the PF is illustrated as Figure 2.5 below.

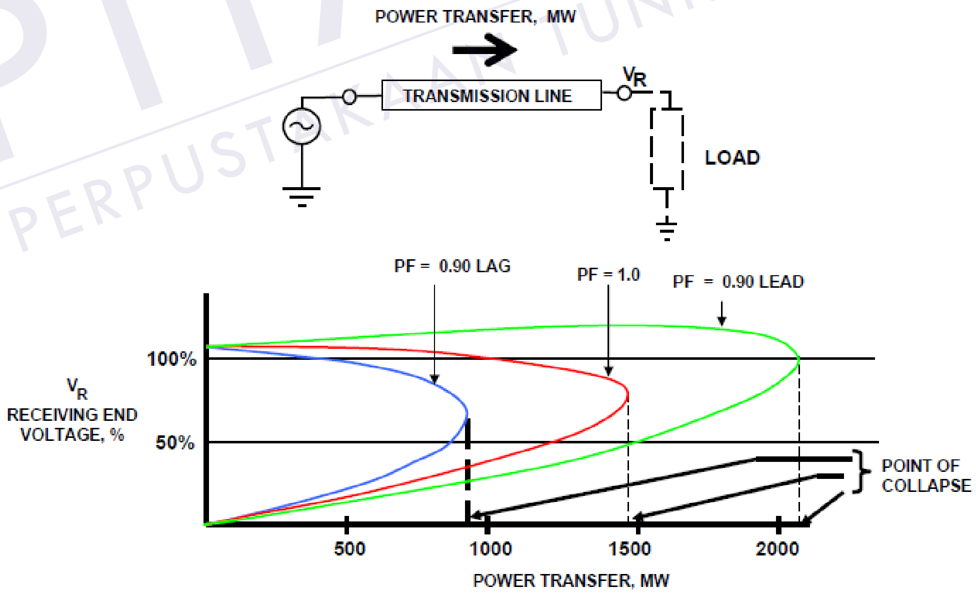

Figure 2.5: Receiving Voltage Vs Power Transfer for different Load Power Factors

Load flow based analyses are used to assess voltage variations with active and reactive power change. Two methods are used to determine the loading limits imposed by voltage stability under the steady- state conditions. The PV/QV analyses can be used to perform analyses in the solution of problems associated with the steady state voltage stability of power systems. They are useful, for to show the voltage collapse point of the buses in the power system network; to study the maximum transfer of power between buses before voltage collapse point; to size the reactive power compensation devices required at relevant buses to prevent voltage collapse and to study the influence of generator, loads and reactive power compensation devices on the network. Voltage instability occurs at the "knee point" of the P-V curve where the voltage drops rapidly with an increase in the transfer power flow. Load flow solution will not converge beyond knee points, indicating voltage instability. Operation at or near the stability limit is impractical and a satisfactory operating condition must be ensured to prevent voltage collapse. Q-V analysis is to determine the reactive power injection required at a bus in order to vary the bus voltage to the required value. The curve is obtained through a series of AC load flow calculations which starting with the existing reactive loading at a bus, the voltage at the bus can be computed for a series of power flows as the reactive load is increased in steps, until the power flow experiences convergence difficulties as the system approaches the voltage collapse point.

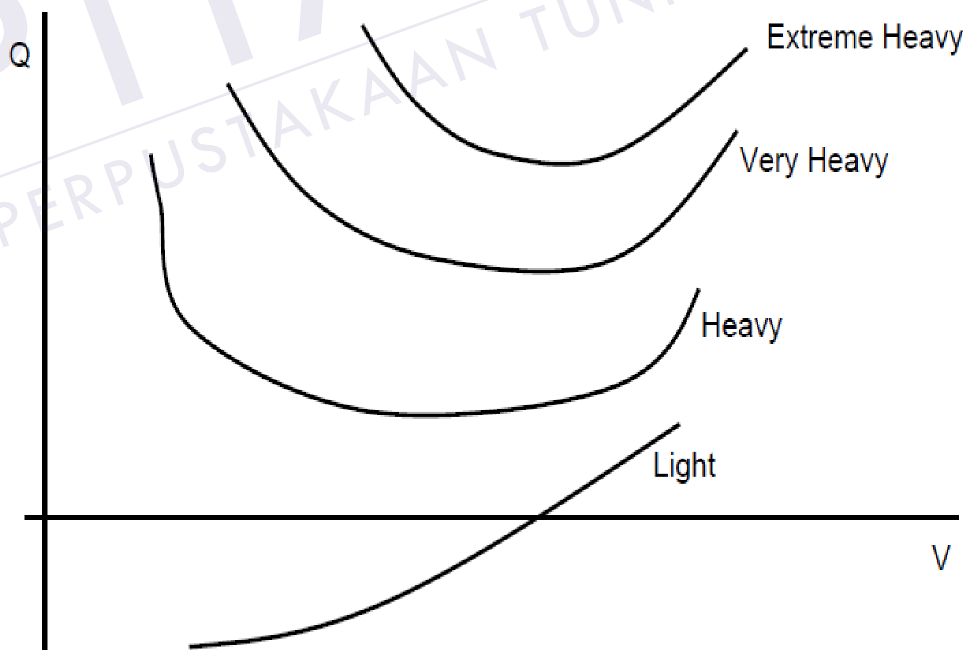

Figure 2.6: Q-V Curves at different loading conditions.

2.3 Description of Previous Methods

Based on the previous methods, it was proven by applying the mitigation measures of identified weaken area through steady state and dynamic analysis, the reliability indices such SAIDI and SAIFI had significantly reduced.

Previous study on transmission reliability evaluation at Laos PDR, the steady-state power flow analysis, at peak demand conditions for the years 2010-2020 by using the program DIgSILENT was examined based on the N-1 contingency criterion, and was found 9 projects for improve the reliability and quality of the system for the years 2010-2020. The results, power losses, ENS, SAIFI and SAIDI outputs before and after added by 9 projects in to system are reduced [3]. The table below shows the results of system performances after added 9 projects in to systems.

Table 1: Variance of system performance after system reinforcement [3]

Fiscal year	ΔP (loss)	ΔENS	ΔSAIFI	ΔSAIDI
	(kW/yr)	(MWh/yr)	(Occ/100 ckt-km/yr)	(Hrs/100 ckt-km/yr)
2010	-10.01	-81.62	-3.27	-1.10
2011	-407.25	-425.20	-4.41	-1.51
2012	-634.48	-795.70	-7.88	-2.63
2013	-3044.84	-1204.67	-11.31	-3.75
2014	-2949.57	-1145.26	-8.94	-2.97
2015	-2849.76	-1336.72	-9.56	-3.31
2016	-2844.82	-1395.55	-8.66	-2.91
2017	-3702.54	-1495.31	-8.39	-2.79
2018	-3577.95	-1633.82	-8.25	-2.79
2019	-3940.86	-1816.91	-8.13	-2.71
2020	-4066.24	-2-27.46	-8.14	-2.73
TOTAL	-28,028.32	-13,358.21	-86.94	-29.19

Under this study, the researcher also conduct economic assessment on the proposed system reinforcement, which based on the results, with reducing the SAIDI and Energy not Supplied (ENS), the projects become economically viable as the Benefit Cost Ratio (BCR) are greater than 1 due to higher benefit compare to the project cost in the long run.

The other study shows because of its wider view of the energy system the EFOM (Energy Flow Optimizing Model) methodology deals with a more aggregated representation of the electric power system than what is classically used in electric power system planning. However, this is often an advantage in the developing countries where detailed data may be unavailable or sporadic. A methodology suitable for this purpose is based on representation of energy flow within and among the sectors [6]. By using the unidirectional graph and liner-programming model, the researcher had modeled the network from primary sources up to end user that all operation cost also included. However, the result might be varies due insufficient data which would be one of disadvantages of this method.

CHAPTER 3

METHODOLOGY

3.1 Project Methodology

This research is adopting the methods approach which involves develops and simulates the case study to enhance Sabah power grid to its reliable operation. Since simulation is based on the collected data, verification of data important so that result generated from the software is accurate and reliable.

The derivation of the lines and underground cables sequence data was conducted using PSCADTM/EMTDCTM software by Manitoba – HVDC Research Centre. It is a simulation tool widely used by electrical engineers for analysing electromagnetic transients of electrical systems particularly in doing planning and operation, design of HV equipment, preparation of tender specifications and teaching and research.

Among some of the typical applications of the PSCADTM/EMTDCTM software are as follows:

1) Over voltage studies during lightning and breaker switching operations
2) Insulation coordination studies
3) Harmonics penetration studies due to FACTS devices
4) Specification of equipment ratings
5) And many other extensive applications of power systems.

All of the above applications require extensive modelling of the power system in order to accurately analyse the response of the power system during a disturbance.

For the Power System Analysis, software that is being widely used is called Power System Simulation for Engineer (PSSE). This software usually uses all the data generated from the PSCAD and will store in the PSSE software. Having accurate and verified data will produce more accurate result and outcome analysis.

3.2 Data collection

In this phase, the data collection and analysis would be conducted. Various data are required to proceed with the system study such as Load Forecast, Generation Planting up Program, Transmission Network expansion program and existing file of PSSE. The Phase 1's flow chart as shown in Figure 3.1 below comprises all preliminary analysis required.

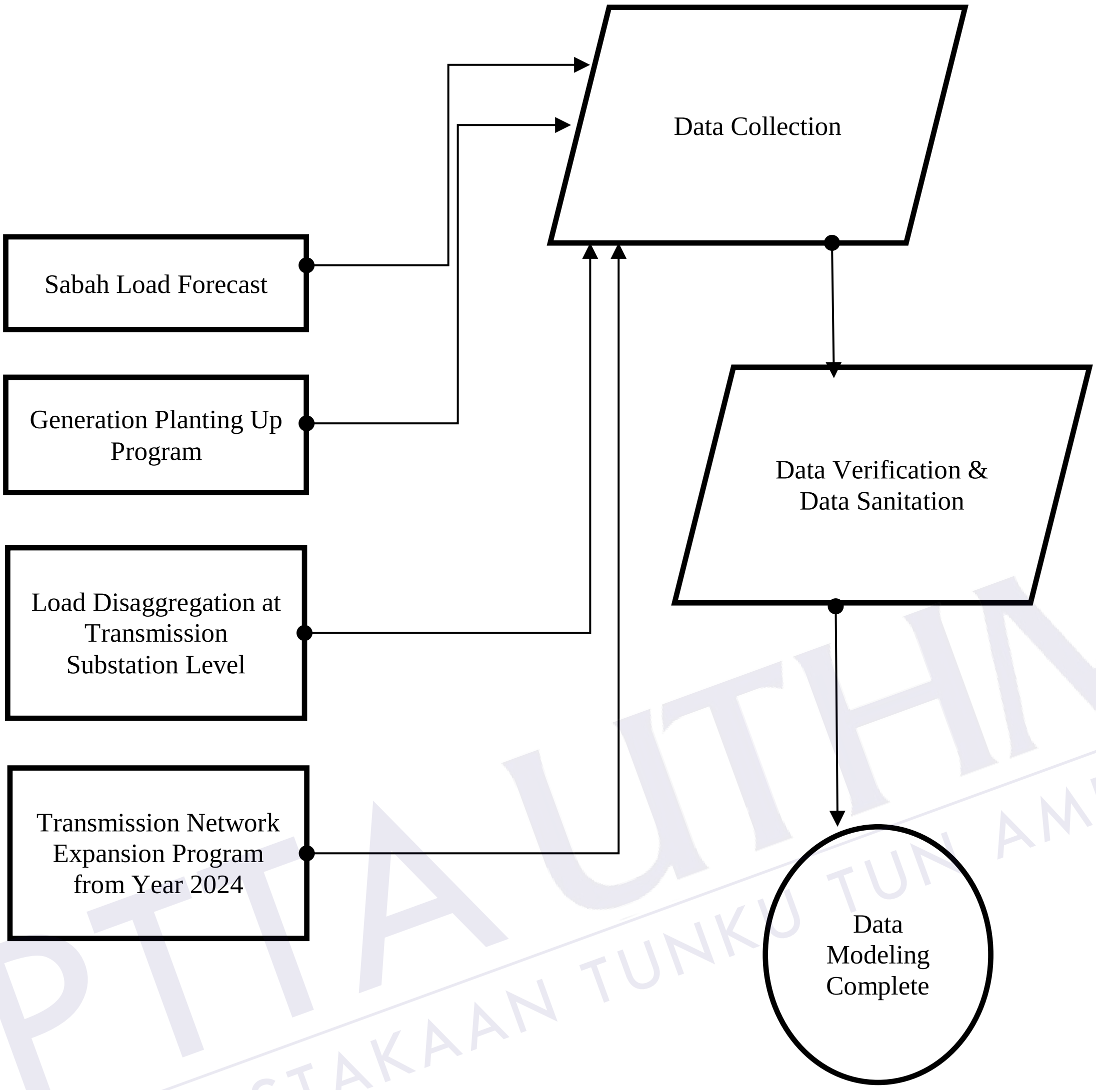

Figure 3.1: Flow Chart of Phase 1

The assumptions used in the analysis are:

a. Voltages at all generation units are scheduled between 1.02p.u. and 1.03p.u.;
b. Power factors of all generating units are maintained above 0.85 lagging;
c. For the existing SVCs at Segaliud and Dam Road S/S, the voltages are scheduled at 1.0 p.u.;
d. All transformer taps are set to nominal;
e. Power factors of loads are assumed at 0.85

Requirement for additional and/or upgrade of existing SVCs is carried out first using steady state analysis. If it is necessary, then dynamic simulation is performed to confirm the requirements.

3.3 Network modelling

In this phase, the input from Phase 1 is required to model the network based on actual scenario of transmission system. The transmission network study will be based on Target Network concept where a future system will be developed which will be adequate and secure to cater for the future load level, in accordance to the Long Term Demand Forecast & Long Term Generation Development Plan as shown in Figure 3.2 below.

In a Target Network concept/approach, after completing the analysis of the Base Case Network, the Target Network for the Year Base + 10 will be developed i.e. Y2013 + 10 = Year 2023.

The result in turn shall be used to assist re-prioritizing the existing and ongoing project (deferment plan or expedite plan) taking queue from the new demand forecast and generation development plan or even trigger a new ad hoc operational measure if any.

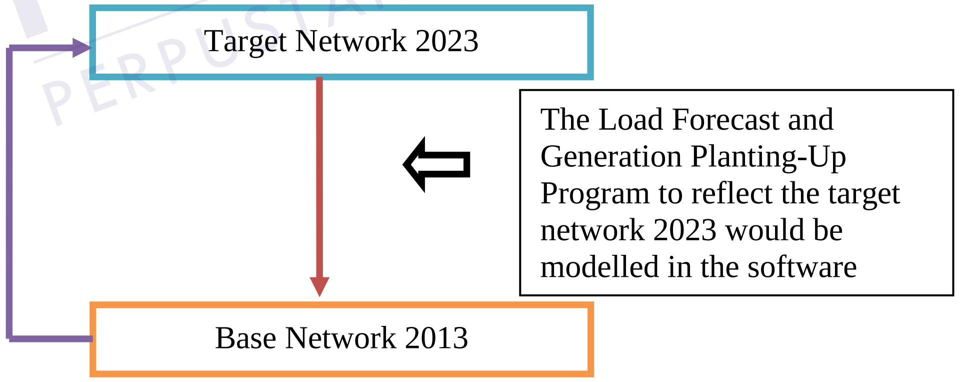

Figure 3.2: Target Network Modelling

With reference to the SLGC, Clause PC 5.1.2, the analysis for each Target Network shall undergo 3 Major Steps as below and benchmarked against the Performance Criteria & Limits:

a. Step 1: Pre-Disturbance State Analysis

b. Step 2: N-1 Analysis

c. Step 3: N-2 Analysis & Benefit Cost Ratio Analysis

The pre-disturbance state of the Target Network Case shall follow the following *Step 1: Pre-Disturbance State Analysis* shown in Figure 10 as below. In summary, in the pre-disturbance state of the transmission system, normally no violations of the criteria and limit are expected, however if found, a mitigation options should be proposed, analyzed, simulated and technically/economically ranked. All the options shall be retest and pass *Step 1:Pre-Disturbance State* each option shall be listed and ranked in a technical-economic list, and the least cost option shall be selected as system reinforcement project(s).

Once the Transmission System – Load Flow Case pass the entire criteria/limit checkpoint, it shall enter into Step 2 shown in Figure 11 as below:

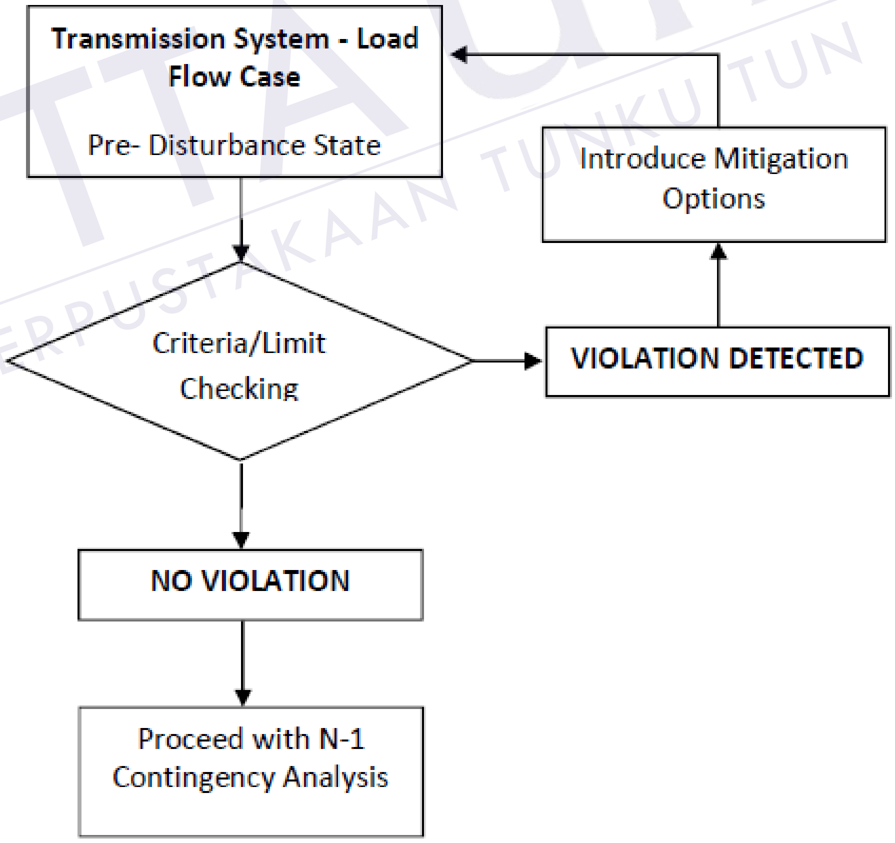

Figure 3.3: Pre-Disturbance Analysis

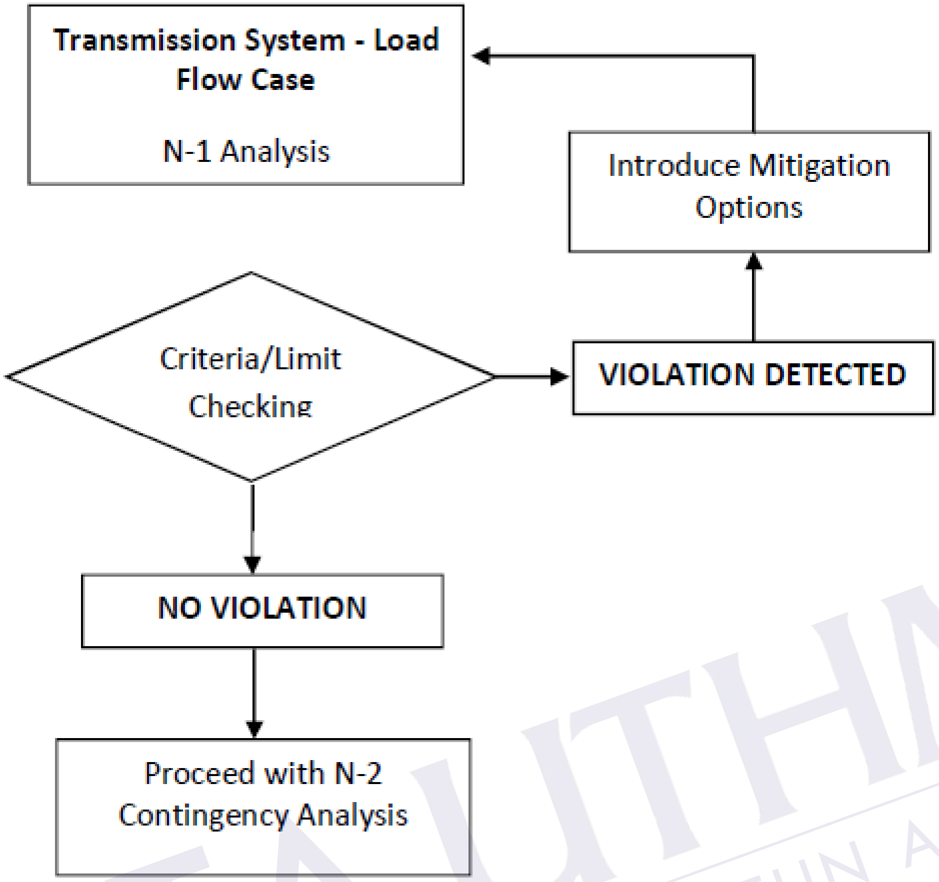

Figure 3.4: N-1 Analysis

In *Step 2: N-1 Analysis*, the Transmission System – Load Flow Case will be subjected to an automated n-1 contingency analysis by invoking the 'AC Contingency Solution' in PSS/E. The PSS/E computer program shall iteratively calculates full ac power flow solutions for a number of specified set of n-1 contingency cases, monitor voltage and loading condition and stores the result in a binary file. The number of n-1 contingency cases shall depend on the number of elements in the system. This feature in PSS/E is a powerful approach as screening tool and for testing large systems with many possible contingencies where the user wishes to monitor specific branches, interfaces or network area for problems.

Each violations stored in the binary file shall be extracted for close attention, and a mitigation options should be generated, analyzed, simulated back in the Transmission System – Load Flow Case. All options shall be retested and pass *Step 1: Pre-Disturbance State Analysis* and *Step 2: N-1 Analysis* shall be listed and ranked in a technical-economic list, and the least cost option shall be selected as system reinforcement project(s).

In *Step 3: N-2 Analysis*, the Transmission System – Load Flow Case will be subjected to an automated n-2 contingency analysis by invoking the 'AC Contingency Solution' in PSS/E. This is also an iterative step that is similar to the Step 2. The PSS/E computer program shall iteratively calculates full ac power flow solutions for a number of specified set of n-2 contingency cases, monitor voltage and loading condition and stores the result in a binary file. The number of n-2 contingency cases shall depend on the number of elements in the system.

Each violations stored in the binary file shall be extracted for close attention, and a mitigation options should be generated, analyzed, simulated back in the Transmission System – Load Flow Case if the N-2 contingency lead to a load loss of greater than 95MW as stipulated in the SLGC, Clause PC 5.1.2. All the options shall be retested and pass *Step 1:Pre-Disturbance State Analysis* and *Step 2:-N-1 Analysis* shall be listed and ranked in a technical-economic list, and the least cost option shall be selected as proposed mitigation option. The proposed mitigation options shall undergo Benefit Cost Ratio Analysis, whereby only the proposed mitigation option with a positive Net Present Value (NPV) shall be considered and selected as system reinforcement project(s).

The flow chart of Step 3: N-2 Analysis is shown in the Figure 3.5 as below.

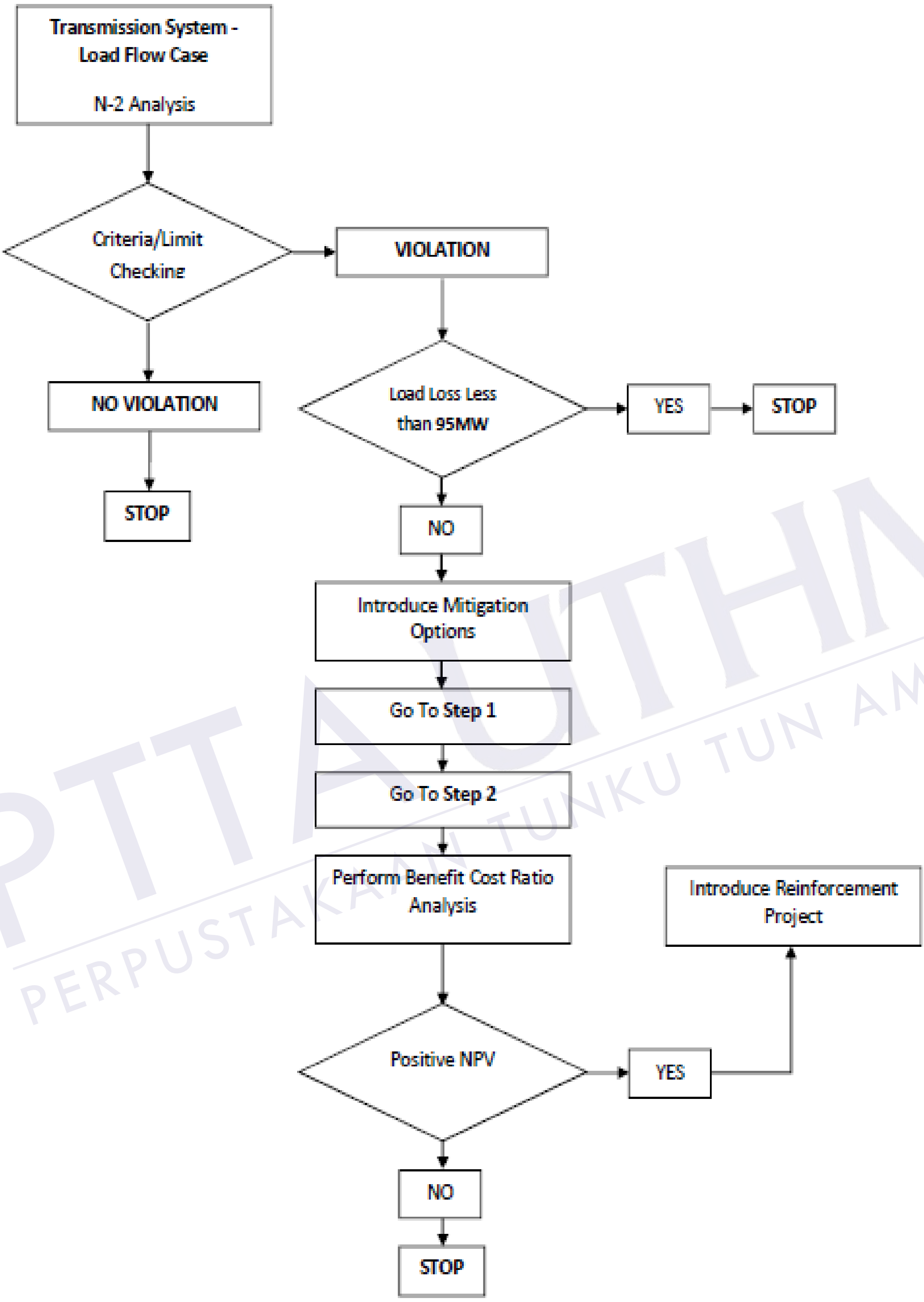

Figure 3.5: N-2 Analysis

3.4 Economic analysis

Recalled that for N-2 Analysis, options that have passed Step 1 and 2 shall be listed and ranked in a technical-economic list, where the least cost option shall be selected as proposed mitigation option. The proposed mitigation options shall undergo Benefit Cost Ratio (BCR) Analysis, whereby only the proposed mitigation option with a positive Net Present Value (NPV) shall be considered and selected as system reinforcement project(s).

BCR is a systematic approach for calculating and comparing the life-cycle cost of the option with the overall benefit it brings to the system. In BCR, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their *Net Present Value* (NPV). Under case study of this project, Southern Link project also called second link to connect the West Coast Grid and East Coast Grid would be used. The project is proposed to mitigate the impact of losing double circuit 275kV Kolopis-Segaliud. This contingency will result in the loss of over 200MW of East Coast Grid (ECG) load.

Figure 3.6: Southern Link Project

3.5 Methodology to conduct BCR Analysis

The following is a list of steps undertaken to perform the Benefit-Cost Ratio (BCR) Analysis.

a. Step 1: Decide the project options to be evaluated under BCR Analysis
b. Step 2: Select measurement(s) and measure all cost/benefit elements
c. Step 3: Apply discount rate
d. Step 4: Calculate net present value (NPV) of project options
e. Step 5: Perform sensitivity analysis
f. Step 6: Adopt the options with positive NPV (i.e. the benefit is more or equal than the cost)

3.5.1 Step 1 – selection of project

Step 1 is to decide on the options. Only project to mitigate failures N-2 with the risk of losing load of more than 95MW requires assessment of BCR. The selection of loss of 95MW under N-1 criteria is to comply with the Sabah and F.T Labuan Grid Code. Any projects under this scenario need to do a BCR analysis.

3.5.2 Step 2 – selection of options

The next step is to define the elements of cost and benefit of the option. Exclusive to this study, the elements of cost are identified as the capital cost of the project and the O&M cost throughout the economic life of the project. The benefit component is defined as the avoided risk or avoided Expected Energy Not Served (EENS) with the mitigation option in place. All benefits and costs are expressed in monetary terms; RM. Figure 3.7 illustrates the elements of cost and benefit in BCR analysis.

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